Experiments in Educability

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REGULATION IN BEHAVIOR

Several years ago there appeared in *Nature* an account of a statistical inquiry into sex determination. The results indicated that children born to young mothers were predominantly girls and that those born to old mothers were predominantly boys. Whether this hypothesis has been borne out by further results I do not know, but assuming it to be a law, it is an example of what has been called regulation in behavior. The purpose which such a process serves is clear. When there is a shortage of women in a community girls are likely to marry when very young, due to the increased opportunity afforded them on account of the under-supply of more mature women. If such marriages result in a number of female infants greater than the normal expectation, the balance between supply and demand is thereby reestablished. A similar compensation is had when, in a society where females predominate, and hence are not married so early in life, male offspring are in excess.

The world is full of instances of this sort. Organisms utilize the very difficulties they encounter in order to bring about the removal of these difficulties. Their make-up insures this regulation. They do not depend on outside guidance to carry them through adverse situations. The adverse situations in combination with an organism are self-eliminating. Of course this is not always true for the individual, but the social group, which is the larger organism, survives because the procreation of its parts is as rapid as their destruction.

We often so construct a piece of machinery that this principle of auto-adjustment holds in its behavior. This is done so that we may not have to manipulate it and direct it to any great extent. The floating ball disconnects the circuit and stops the pump when the tank is full. The pendulum swings to one side and releases the air pressure which tilts the wing tip of the aeroplane when a gust of wind causes it to pitch or roll, and this restores equilibrium. The electric

sterilizer is supplied with a soft metal plug which melts off and releases a spring, so breaking the circuit, when the water is exhausted. Otherwise the rheostat would be burned out. But now the heat prevents itself from being dangerous. A general statement of these and other forms of regulation might be valuable. It might indeed serve as a rule of thumb for inventors.

Bancroft[1] gives many excellent examples of regulatory behavior as illustrating his "universal law." This law is that "a system tends to change so as to minimize an external disturbance." Some of the cases he notes are:

The readjustment of prices through supply and demand.

Tears caused by and discharging an irritating substance from the eye.

A splinter causing its own sloughing out.

In chemistry, the occasional prevention of further reaction by some reaction products.

An insult causing a response which may prevent further insult.

The bending of trees to spill the wind.

It is certainly tautologous to say that organisms behave along lines of least resistance, for our only definition of least resistance is the resistance that a system is first to overcome. But any suspicion that the statement of Bancroft's law falls short in a like way of being a synthetic judgment, is removed after he has clarified it by illustration and comment.

Adaptation of a group of animals or plants *by selection* is a case of regulation if we regard the group as an organism. The capacity for all the responses is not resident in all the individual animals or plants, but is distributed among the parts (individuals) of the entire organism (group). The existence of the organism is maintained along with the life of those parts which respond adaptively to the present condition, notwithstanding the death of those parts which are not adjusted so to respond. This is shown in the adaptation of wheat to climate. A bushel of late ripening wheat will

[1]Bancroft, W. D., "A Universal Law," Jour, Am. Chem. Soc., XXXIII., No. 2, February, 1911.

contain some grains of early ripening wheat. Planted under certain conditions, these latter alone will mature, but they will serve as seed for the next crop, which will inherit their characteristics for the most part, and which will be almost entirely early ripening wheat.

When an apparently new structural adaptation is developed in an organism by a set of new conditions, the presumption is that the organism's capacity for this change of structure was previously resident in the organism, and not that the change was wholly caused by the new condition. The condition was the necessary factor which had to be added to the organism's potential capacity, in order that the adaptation should result. An organism may in this way be so adjusted as to respond adaptively to any one of a number of possible conditions which may be mutually exclusive. So when one response is realized, the others may be latent. This is shown by the substitution of hair for wool in the coat of a sheep that is taken to a warmer climate. In the domain of behavior a similar rule is obvious. Here a given stimulus calls forth a particular reaction which is especially fitted to the situation.

The Vital Manifold

Organisms living in an environment of changing conditions are, for the most part, constantly readjusting themselves to the change. They avoid bad conditions and seek better. Or, when an unfavorable condition can not be avoided, a change takes place in their structure which makes it possible for them to live in that condition. If, when in a certain medium some metabolic change takes place in them, which to be set right demands some other medium, they seek out that other medium either by trial and error reactions or, following certain clues present in their surroundings, by some specially appropriate instinctive or habitual reaction. If we admit that such processes are regulatory, we have made a beginning towards defining regulation. We may further say that it is characteristic of organisms having a certain struc-

ture. It is the result of the interaction of such organisms and their media. The organism and the media constitute a manifold which, though constantly operating, so functions as to prevent disintegration of the organism. The life-long stability of arrangement possessed by the organism and its offspring further differentiates it from the media and makes most significant the distinction between biology and the inorganic sciences. The field of the science of animal behavior of which the processes in such a manifold constitute the data, is in part hardly to be distinguished from some of the subject-matter of dynamic biology. The former science, however, always classifies these processes on the basis of the *regulation* which they display.

Negative Regulation

Regulation occurs when any process in the manifold which reduces the stability of the organism results in such a change, either in the media (through the organism's migration or otherwise) or in the organism itself, that the stability of the organism is regained, so that the deviation toward instability has come to be *the cause of its own remedy.* Such regulation is the *avoidance* of those states in the organism or of those conditions in the media which are or have become unfavorable to the stability of the organism, so let us call it *negative regulation.*

Frequent examples of negative regulation are found in the behavior of inorganic manifolds, of plants, and of the lower animals. When a boat in a heavy sea rolls to one side it rights itself into the perpendicular again. It does this because of the fact that the further it tilts from the perpendicular the greater is the leverage by which the pull of gravity, which tends to bring it back, is applied. Its behavior conforms to our definition of negative regulation. The way in which paramoecium retains favorable conditions must be described by the same principle.[2] The valve action at the boundary of the optimum will work for the animal's good in

[2] Jennings, "Behavior of Lower Organisms."

either novel or familiar conditions. A river (organism) shows regulation in migrating from its original channel to one of greater stability, and in overcoming obstacles, such as log jams or landslides, which serve as the cause of their own remedy.

In the above examples correction is *the result* of the excess of process, or deviation from stability. The correction and the condition which needs correction may, however, both be the results of the same cause, having no causal effect on each other. For instance, in crayfish oxygen starvation is corrected by the very activity which causes it, namely, walking. The gills are placed so as to be moved by the legs, for which reason walking causes both depletion and repair of the oxygen content of the blood. Another example is found in the protective color changes in the coat of northern mammals. These changes are possibly not the result of the color environment (the seasonal variation of which is a deviation toward instability), but rather the result of some accompanying condition such as food or temperature plus certain internal factors. That is, the brown fur does not become white because of the whiteness of the snow. The cause to which is due in part the occurrence of the snow, namely, a decrease in temperature, is largely responsible for the adaptive change in the color of the fur. Again, for example, the sunshine which on a summer day would otherwise overheat a man, is in part the cause of the breezes which assist in keeping him cool. The cause, that is, which produces the deviation from the optimum brings about also a condition which helps to restore the optimum.

We may then occasionally find this relation between the deviation from stability and its means of correction. The mutual cause of these two processes may indeed be indefinitely remote. This phase of regulation is not recognized in the above definition, so we may add: *Negative regulation also occurs when a process in the manifold which is the cause of a deviation from stability results independently in its correction.*

Positive Regulation

An organism may be so constituted that it reacts to some condition which is favorable, adapting itself so as to obtain benefit from it, even when failure so to react to the condition would cause it no more harm than the loss of an unusual benefit. This form of reaction is sometimes given to a condition which the organism does not reach by locomotion, such as a condition which is generally periodic and has no fixed spacial position(*e. g.*, a weather condition). But if the organism has means of locomotion, the reaction more usually involves a movement toward the favorable condition. This favorable condition may be only occasionally present or it may be only occasionally needed by the organism. The favorable condition to which the organism reacts may be at a distance from, or may impinge upon, the organism. If it is at a distance it must act mediately upon the organism and the organism must have the power of locomotion in order to take advantage of it. The favorable condition may be relatively fixed in space, such as air at the top of the water, or it may be relatively fixed in time, such as the regular recurrence of sunlight. To distinguish this form of regulation let us call it positive.

Positive regulation occurs when some change in the environment or in the physiological state of the organism causes such an adaptive reaction of the organism or such an alteration in the media that the interaction of the newly arranged organism and media which follows brings about increased stability in the organism. In such a process both organisms and media have a double function. The media act first as the stimulus to the organism's adaptive reaction and second as a contributing cause of the increased stability of the organism. The organism likewise must be set or arranged to adjust or orient itself to the changed conditions and also to interact with the novel media so as to cause increased stability in the new relation. The squirrel's storing its food,

the butterfly's seeking its mate, and the prospector's digging for gold are all examples of positive regulation.

In positive regulation the favorable condition and the adaptive change do not always have the direct relation of cause and effect. They may be as well results of a single cause. This is especially true in the higher forms of behavior, such as the behavior of a group of sympathetic organisms in a colony or society. For instance, Greek philosophy was a cause which has ramified into many results. Largely because of it, and of the development which it caused, the present-day students write their books on science or philosophy, because of it there are laboratories, without which these books would have lacked much material, and printing presses, without which the volumes would never have reached their readers. That same early philosophy is the inheritance of the people and without it the modern book would not be understood. As another example, when the hot weather in spring impels birds to migrate northward it causes also those changes in the country further north which produce food and the proper conditions for raising the young. So we may add: *Positive regulation occurs when a process in the manifold which is the cause of some potentially favorable condition results independently in an adaptive change by which the organism takes advantage of it.*

Both positive and negative regulation may take place as the result of a change merely in the physiological state of the organism and not be due to any variation in the media. Negative regulation is seen under such conditions in the reactions of the over-fed sea anemone away from food, or in behavior of a dog that after a time moves further away from a fire the heat of which had at first attracted him. Positive regulation takes place under like conditions when respiration is increased due to exercise, or when the hungry animal goes out to search for food to which previously it had been indifferent. Judgment and reason in the higher animals furnish the best examples under these conditions for positive regulation. Positive regulation usually results in an

increased margin of stability which is insurance against future dangers and permits the organism some rest from the activities of negative regulation. The two forms of regulation are combined in the food reaction of most animals. Hunger results in migratory search after food as well as in its capture. Many animals, however, capture food for future use when the conditions of negative regulation are not present. The two forms of regulation are, for instance, combined when a man rises in the morning partly because he is no longer comfortable in bed and partly because he hears the water running into his tub.

The direct interaction between the conditions existing at any given time as well as the resulting adaptations in the manifold may be described as follows:

In negative regulation unfavorable media (present or at a distance) may cause a change in the organism that makes it either resist such media, or avoid or migrate from such media, or analyze or synthesize such media into innocuous or favorable media. Or some unfavorable part or process in the organism may cause its own elimination or discontinuance, either by interaction with the media, or by action within the organism, or by both of these.

In positive regulation favorable media (present or at a distance) may cause a change in the organism that makes it either interact with such media or enter into or migrate to such media. Or innocuous media (present or at a distance) may cause a change in the organism that makes it analyze or synthesize such media into favorable media. Or some favorable part or process in the organism may cause its own maintenance or continuance, either by interaction with the media or by action within the organism or by both of these.

EXPERIMENTS IN EDUCABILITY OF PARAMOECIUM

Reactions to Touch. The purpose of the following experiments was to determine what kind of modifiability is shown by Paramoecium due to recurring experiences of the same kind. For this purpose first a capillary tube was selected of a bore smaller than the length of the Paramoecium and larger than his width. The animal was caught by the upward suction of the tube and the tube was then placed on a movable carriage, so the animal could always be kept in the field of the microscope no matter what part of the tube it might be swimming through.

Once in the tube the Paramoecium swims to the forward end and upon reaching the meniscus jerks backward for several times its own length, then approaches again in a wider spiral than before. This backing and approaching takes place at least a dozen times and later the Paramoecium settles down to a pecking movement, revolving anti-scriwwise about the meniscus and attacking about five places in its circumference.

In the original approaching and retreating both movements may be either screwwise or anti-screwwise. In approaching, both the screwwise and anti-screwwise movements give about the same width of spiral, namely, a very slight one. If the retreat is made anti-screwwise a relatively straight course is followed, the spiral being hardly noticeable. If the retreat is screwwise a very wide spiral results.

In most cases the animal after a varying time bends its anterior end around toward the aboral side, forming a "U" with its body, and after a number of jerks succeeds in reversing the position of its body in the tube. In all cases it turns toward the aboral side, thus using the long creeping cilia near the buccal groove to obtain a hold on the side of the tube.

As this facing about in the tube is repeated, the time taken for each turn may be longer than for the last, the animal finally dying of apparent fatigue, or, if the tube is not so small that too violent an effort is required of the animal, the time may gradually be shortened and a most surprising aptitude of turning be developed. Paramoecia from a vigorous culture give better results than poorly nourished ones. Under optimum conditions there was found a reduction of turning time, after the animals had been in the tube for twelve hours or more, from four or five minutes to a second or two, which is the minimum time in which the turn can be made.

Often the Paramoecium will rest for a long period at once meniscus, slowly circling around with its buccal groove resting against the air surface. When, however, the effort is made to reverse, the shortening of time in the practiced individuals is very apparent.

Reactions to temperature. In these experiments a capillary tube was selected large enough to allow the Paramoecia to reverse their direction without touching its sides, and in which two Paramoecia could pass each other without difficulty. A number of individuals were taken up in this tube and the tube was placed on a carriage having two large glass supporting tubes through which water of different temperatures was passing and on which the capillary tube rested.

While hot water was flowing through one support and cold water through the other the temperatures could be reversed, so that the cold water would flow through the one and the hot water through the other. Thus the distribution of temperature in the capillary tube could be reversed. By cold water is meant water at normal temperature to which the animal gives no reaction.

As soon as the capillary tube is heated at one end by contact with the hot support, the Paramoecia at that end dart about at random until they are headed toward the cool end of the tube and even then do not swim to the cool end

at first but often turn back to the hot end several times before finally swimming over to the cool water. Once arrived at the cool end the Paramoecia do not stay there, but turn and start back to the hot water. In this way a Paramoecium may traverse the length of the tube a dozen times or more before coming to rest at the cool end of the tube. As the animals leave their resting place at the warm meniscus in obedience to the repeated reversing of temperatures in the tube, their movements become slower and more regulated and they seldom turn more than once toward the cold water before swimming in that direction. It is not significant to express this modification of behavior in terms of time for, although the time involved in getting away from the heated end of the tube is somewhat reduced as the stimulus recurs, it is the suitability of the movement to accomplish the result which characterizes the later reactions. In these the actual locomotion, is slower but the random movements give place to more determined ones.

The influence of an associated past experience upon the reaction to a given stimulus. Although in the following experiments the observations gave nothing but negative results, these results serve to fix the limits of educability in Paramoceium. Although Paramoecium profits by experience, as seen in the above sections, it does not show associative memory such as Loeb would demand as the criterion of consciousness.

The conditions of the first experiment were these. Paramoecia were placed in a trough having an extremely thin glass bottom and this trough was immersed in a partitioned box containing hot and normally cool water on the two sides, so that the bottom of the trough was kept cool on one half and warm on the other. There was a distinct line, not corresponding exactly to the partition of the under box, at which the Paramoecia approaching from the cool side would turn back. A light was fixed above the trough and a screen interposed so that a shadow fell covering the warm area and a minute part of the cool area beyond the reaction line. The white Paramoecium which was here used, gives no re-

action to light or darkness and it was hoped that by allowing the animals to experience darkness whenever they experienced heat they might, when the heat was removed, react negatively to darkness. This they did not do, however, though one group of Paramoecia were allowed to experience the two conditions together for fifteen hours, one for twenty-four hours, and one for forty hours.

Another experiment of a somewhat similar kind was performed in which it was tried to bring about the association of heat and gravity. A small tube was bent into an L shape and, after some Paramoecia had been drawn up into it, was placed so that one leg was horizontal and the other, rising from this, was vertical. At the top of the vertical leg was placed a hot metal rod in contact with the glass and kept at a constant temperature. If Paramoecia show geotropism, (More: Am. Jour. Phys., vol. 9, pp. 238 ff.) this irritability to gravity should be more easily associated with heat than could light, which, although it must make some impression on the organism, does not cause normally an avoiding reaction.

Whenever, the Paramoecia swam up the vertical leg of the tube they received a heat stimulus which caused them at first to jerk backwards and after many random trials to swim downward to the cool water. Although these conditions were kept unchanged for as long as three days the Paramoecia never learned to avoid the vertical leg of the tube. In the end they did not react as violently to the heat and did not, as at first, swim occasionally past the hot metal rod. Also they seemed later to develop greater sensitivity, reacting to the heat before getting as close to the metal rod.

CONCLUSION

Paramoecium is educable in that its behavior may be modified to show the results of practice, both in a reduction of the time involved in performing a movement and in the increase in suitability of the movement to accomplish the appropriate result.

In so far as the tests here apply, there is no evidence of associative memory in Paramoecium.

The reversing movement above described is in the nature of a *positive reaction.*

SOME RESULTS OF TRAINING A GUINEA PIG

Description of the Maze.

The maze used in these experiments consisted of a straight passage which ran for eighteen inches from the entrance to a point where two other passages turned at right angles from it, running to the right and to the left. Three inches beyond this point the right passage turned again to the right and the left passage to the left, both opening through doorways into an area outside the maze.

Doors were made of sheet zinc and were swung from the top. The exit doors could open only outward and the entrance door could open only inward. Thus the animal having entered the maze could pass out through the exit doors. These doors were provided with hooks by which either could be locked at will. The outside measurement of the box was seventeen by twenty-six inches.

In order to pass through the maze the animal entering had to choose either the right or the left passage. This choice was involved in most of the following experiments with the maze. An albino male Guinea pig was used as the subject in these tests. He was about four months old when first used and about seven and a half months old when the tests ended.

Habit Formation in the Maze.

The Guinea pig had been accustomed to come to the edge of his cage, when the side of it was rapped on, in order to get a bite of carrot which was held in the experimentor's hand. In this first experiment the carrot was held in the first passageway of the maze and knocked frequently against the wooden side. The Guinea pig being outside the entrance door, reacted, as he had learned to do in his next box, by hunting about for the carrot in the neighborhood of the source of sound.

After the pig had learned to enter the entrance door he was allowed to do so and here to eat a little of the carrot,

which was then removed and rapped against the wood beyond the right doorway. The left doorway was locked. After the first trial, rapping to indicate the position of the food was left off. The carrot was shifted back and forth and the time taken by the pig to follow through the respective doors was recorded. This measurement began when the pig had just finished chewing one mouthful and was reaching for another, the carrot being removed at that time. The measurement ended when the animal had passed through the door and it had fallen shut behind him. Thus there were two series of measurements; one of the time taken to enter the maze and one of the time taken to leave it. These are expressed in the following table. The trials in each series were taken consecutively, a period of several hours elapsing between the series.

Into Maze	No. Trials	Av. of All	A. D.	Av. First 3.	A.D.	1st Trial
Series 1	11	168.9	222.6	553.	324.7	1040.
Series 2	4	22.8	11.8	14.	7.3	3.
Series 3	5	5.	1.6	6.3	1.1	5.
Series 4	8	27.1	36.7	6.	3.3	4.
Out of Maze						
Series 1	11	69.	75.8	208.	69.3	312.
Series 2	4	20.5	18.2	20.	24.	3.
Series 3	5	4.2	1.8	4.3	2.4	8.
Series 4	8	34.4	44.1	6.3	3.1	5.
Series 5	10	59.1	49.9	19.3	3.8	25.
Series 6	18	8.4	3.4	3.7	1.1	4.

The measurements in all the tables are given in seconds.

Antagonistic Habit Formation and Cross Training.

After an interval of one hundred and three hours, the Guinea pig was returned to the maze. This time the right door was locked and the left door was unlocked. There was no difference in appearance, that would be noticeable to the pig, between the maze now and before, because the means of locking the door was a wire nail, driven into the wood at the side of the door and bent to an angle of ninety degrees, which could be turned so as to prevent the door from swinging and was visible only from the outside. A turn in the direction opposite to that which the Guinea pig had learned had now to be made before he could leave the maze. The carrot was concealed until the Guinea pig had left the maze and was then given him as a reward.

In the following table is noted the time and accuracy of the guinea pig's forming the antagonistic habit of making the left turn. Only his reactions in leaving the maze are noted, his entering being disregarded. Fractions are omitted, the next higher whole number being used.

Series	No. Trials	Av. Time	A. D.	% of Errors
1	6	113	165	50
2	11	11	14	9
3	4	3	1	0
4	17	2	1	0

After an interval of forty-eight hours the conditions of the first part of the experiment were resumed, namely, the left door was locked and the right door was left open. The results are shown in the following table.

Series	No. Trials	Av. Time	A. D.	% of Errors
1	15	11	7	41
2	7	5	2	0

After an interval of six hours, the conditions were again reversed. In the following table are shown the confusion effects.

Series	No. Trials	Av. Time	A. D.	% of Errors
1	15	22	19	67
2	25	9	4	40
3	11	8	3	37

The Guinea pig seemed to compensate for his inability to form the left turn habit, as previously, by his greater quickness in making a practical trial of both doorways. He learned that if one door was locked the other was open and he substituted a method of trial and error for the docility of the former experiments. Further, he acquired a negative reaction to the sight of the locked door, which he remembered was locked often without trying it, that took the place of the lacking positive reaction to the unlocked. The general conclusion from the above results is that frequent alternation of the opposite conditions reduces the adaptability of the Guinea pig for either of the these conditions when it is afterwards maintained constantly. This last method of reaction of the Guinea pig's was well suited for the experiments in Movement-odor Association described in the following section.

Movement-odor Association.

A watch glass covered with a perforated sheet of zinc was placed at the end of the long passage at which point the Guinea pig had to choose between the right and left turns. When the left door was open the watch-glass contained a piece of absorbent cotton saturated with oil of peppermint. When the right door was open this watch-glass was replaced by another containing tincture of assafoedita. Care was taken that the two watch-glasses should offer the same visual appearance and also that the maze should be well aired between each change. As the time of the turning reaction was so largely dependent on the pig's state of hunger and fatigue the measurement was of right and wrong cases only, no record being taken of the time.

At first twenty-four series of three trials each were taken, the odors and the unlocked doorways being alternated every three trials. The Guinea pig was considered to have failed in every trial in which he tried the locked doorway. No punishment was used at the locked door.

Considering the first six series and the last six series under each of the two conditions, making groups of eighteen trials each, the results were as follows:

Peppermint and Left Turn	Per cent of Right Cases
First six series	55.5
Second six series	38.8
Average	47.15

Assafoedita and Right Turn	Percent of Right Cases
First six series	44.4
Second six series	50.
Average	47.7
Average of all 72 trials	47.4

The above series extended through two weeks. During the next eight days seventy-two more trials were taken, equally distributed between the two conditions, that is, between the occurrence of assafoedita and the open right door and peppermint and the open left door. In these trials a random order of presenting the conditions was used, but the same set of conditions never occurred more than twice consecutively. The results were as follows:

Percent of Right Cases

Peppermint and left	58.3
Assafoedita and right	47.2
Average	52.7

The Guinea pig showed that he detected the difference between the assafoedita and the peppermint for he would often draw back from the assafoedita and then pass it rapidly, always taking care to jump over the watch-glass. He usually acted in this way when the assafoedita was first presented after an interval of some hours, and he never acted so toward the peppermint.

The results are not ground for assuming that the Guinea pig benefited at all from the practice, although the practice was equal in amount to that which was sufficient for creating the spatial association of the previous experiment.

Experiments to determine the guinea pig's ability to give different specialized reactions to two sounds were negative.

Experiments to determine the Guinea pig's ability to associate different end terms with two series of motor reactions, gave fairly positive results, showing the characteric reduction of time and errors.

SOME RESULTS OF TRAINING A WHITE MOUSE

An albino mouse was used in these practice experiments. The conditions were as follows:

A drop-bridge apparatus was used which consisted of a disc of pasteboard mounted on an inverted glass tumbler, on the top of which the animal could walk about but from which he could not descend. There was a hinged bridge which could be propped up out of reach of the animal but which might be lowered by pulling a string which passed above the disc. The string was attached at one end to a fixed rod and at the other to the prop which held up the bridge. The prop was made in the form of a toggle joint, the system being barely in equilibrium. This made necessary only a slight pull on the string in order to cause the bridge to descend, and the position of the prop was so adjusted as to require just slightly more than a chance touch on the string to bring about the fall.

When the bridge had descended it formed part of an incline which led to the ground, where food was provided. There were two motives which might lead the animal to come down from the disc; the presence of the food below, and the restlessness or general diffusion of energy which caused the animal to move about.

At the first few trials, the mouse tried to descend by climbing down the sides of the tumbler, but he found this impossible. As a result of his random movements he finally (after 165 seconds) pulled the string and the bridge fell into place. To this he paid no attention, apparently not realizing that it led to the ground. Twice, before he at last managed to climb down the bridge, he ventured along it a few steps but returned to the disc on top of the tumbler.

The most rapid practice results were seen in the habit of descending the bridge after it had been dropped, the habit of pulling the string being slowly and never perfectly learned, that is, the mouse always combined the characteristic climbing-down movement with the string pulling. He would get his nose over the string and then lean over the edge of

the disc, making scrambling movements with his feet. He need not have leaned over so far, as the bridge dropped with less pull on the string, and he could have omitted, for the most part, the foot movements, so that the reaction was not reduced to the greatest efficiency.

These movements, however, were always made on the side where he could reach the string, even though he sometimes wandered about the disc at random. After a lapse of five weeks he did at first revert to his old attempts to climb down anywhere, but this reaction was soon corrected.

In the following table are stated both the time the mouse took to drop the bridge after being placed on the disc and the time he took to descend to the ground after the bridge had been dropped.

TABLE

		Dropping Bridge		Descending	
Series	No. Trials	Av. Time*	A. D.	Av. Time	A. D.
1	6	58	53	37	42
2	8	27	14	41	47
3	3	12	5	5	1
4	3	10	4	6	2
5	3	11	5	9	2
6	4	18	11	7	2
7	6	13	9	10	5
8	5	13	8	14	11
9	3	12	6	9	2
10	4	10	6	8	3
11	3	38	10	80	42
12	6	24	16	36	47
13	4	10	6	7	2
14	5	6	3	9	5

*Time given in seconds.

The time elapsing between the tenth and the eleventh series was five weeks, whereas that between all other adjacent series averaged twenty-two hours, with a maximum interval of thirty-six hours.